Bull. Astr. Soc. India (2007) **35**, 533–538

Low latitude Pc1 pulsation as observed from ground-based search coil magnetometer

A. K. Sinha*, B. M. Pathan and P. Vohat
Indian Institute of Geomagnetism, Navi Mumbai 410 218, India

Abstract. Magnetic data from searchcoil magnetometer in the Indian sector have been analyzed to study geomagnetic pulsations in the near equator low latitude region (geomag. lat.$< 20^o$). Apart from normal Pc4 pulsations (which is expected at such location), we observe the presence of Pc1 oscillations (frequency $\sim$ 4 Hz) which are very unlikely at these latitudes. The interesting aspect of these observed pulsations is that they follow a broad-band spike during post-sunset and pre-dawn hours, whereas during day time the absence of broad band spike and simultaneous enhancement in the power of Schumann resonance was observed. Observations suggest that these two types of Pc1 pulses are sustained by different energy sources.

Keywords : low latitude pulsations – Pc-1 – lightening – ionosphere

1. Introduction

Ultra Low Frequency (ULF) oscillations in geomagnetic field variations with frequency ranging from few mHz to few Hz have a history of almost a century. Their existence in different frequency regimes and geographical locations have been established through ground-based monitoring of geomagnetic field variations. With the dawning of satellite era, in-situ measurements have confirmed that these pulsations are of magnetospheric origin and are consequences of the response of geomagnetic field lines to disturbances caused by various mechanisms in the magnetosphere (Sinha & Rajaram 2003). Field lines not only respond to the disturbances in the magnetosphere, but also to the ionospheric conditions at their conjugate points in the ionosphere (Sinha et al. 2002). Pulsations in the higher frequency band (Pc1-type) is difficult to be observed on the ground because of

*e-mail:ashwini@iigs.iigm.res.in

ionospheric shielding (Hughes & Southwood 1976). Ionospheric Hall current screens horizontally varying short scale signal from the ground. Also, wave energy is lost due to Joule heating for finite conducting ionosphere. Nevertheless, if there is sustained mechanism for energy feeding locally, these waves can be observed. That is why these pulsations in the higher frequency band (Pc1) are more commonly observed in high latitude regions as compared to mid and low latitude regions. Energetic charged particles from solar wind find entry into the auroral regions by travelling along the field line and act as feeder for host of waves and instabilities at high latitudes. There have been considerable studies of Pc1 pulsations in low latitude regions through ground based measurements. Webster and Fraser (1985) from two spaced stations (L=1.9, Geomag. lat. $\sim 43°$) showed that observed Pc1 pulsations have source inside plasma-pause region. These waves propagate in ionospheric waveguide and gets recorded at the ground. However, in their analysis the effect of ionospheric irregularities were not taken into account. If we go further down to lower latitudes near the equator, F-layer irregularities during post sunset hours will have an important role to play in sustaining these oscillations. Moreover, a band of Elf emissions during lightening activities, which at times get intensified in the subtropical regions also could act as feeder for these oscillations. Intense lightening activities are the features of subtropical regions confined to the geomagnetic latitudinal belt of $\pm 20°$ (Nicklaenko & Hayakawa 2002). Near equatorial region may not only be passively amplifying the current system imposed from elsewhere, but could also be an active source of generation of geomagnetic disturbances (Saito 1983). Pc1 pulsations are ion cyclotron waves generated in the equatorial region of the magnetosphere by proton cyclotron instability (Webster & Fraser 1985). The waves propagate in the field aligned direction down to the ionosphere and propagate via the F_2 region ionospheric duct from the secondary ionospheric source at the foot of the field line to higher and lower latitudes.

Schumann resonances are earth-ionospheric wave guide modes with fundamental around 8 Hz with subsequent harmonics at 14 Hz, 21 Hz and so on with 2% of diurnal variation (Sentman 1996). They act as proxies for lightening activities which is more prevalent in subtropical region (Nicklaenko & Hayakawa 2002). Local increase in lightening activities cause the enhancement in the intensity of Schumann resonance. Such increase in lightening activities results into the increased emission in the elf range. These elf waves can act as feeder for Pc1 pulsations in terms of secondary ionospheric source at the foot of the field line. We call such pulsations as Lightening Induced Pulsations (LIP) and are characteristics of subtropical regions. These pulses are of shorter duration as compared to normal Pc1 pulsations at low latitudes which are away from the subtropical regions (cf. Webster & Fraser 1984). In the near equatorial region, ground observations of geomagnetic field variations have special role to play as low L-value field lines are almost glued to the ionosphere and it becomes very difficult for spacecraft to track these field lines. For preliminary studies we have analyzed one month of ground magnetic data from a set of search coil magnetometers deployed in the subtropical Indian station at Allahabad (Geomag. Lat. 16.05°N, Geomag Long 155°E). Apart from normal Pc4 type pulsations (freq.$\sim$ 10 mHz), we observe Pc1 type (freq.$\sim$ 4 Hz). The role of increased lightening activities (depicted by enhanced Schumann resonance intensity) in sustaining

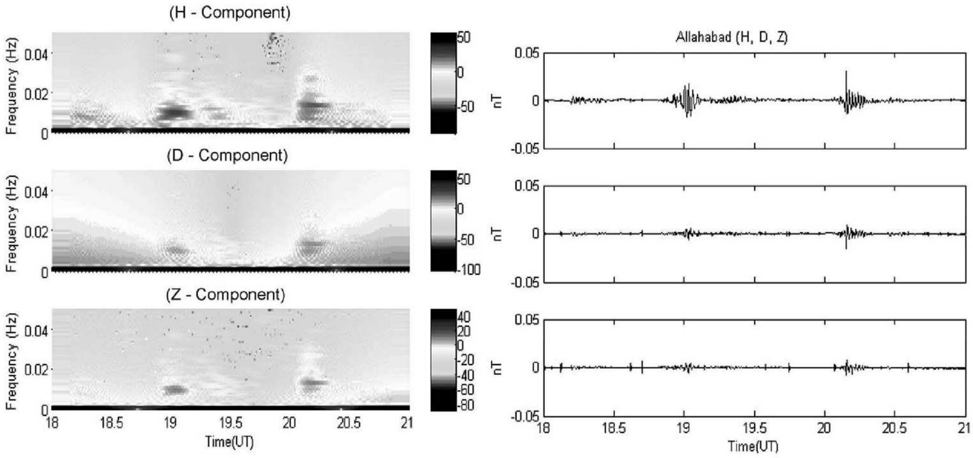

Figure 1. Typical Pc4 pulsations as observed on 01 April 2005. The left panel is the dynamic spectra of X (N-S),Y(E-W) and Z (Vertical) components of geomagnetic field variations and the right panel shows the corresponding temporal variations.

these pulses have been examined. We could not examine the role of night time ionosphere as we could not get hold of either scintillation or ionosonde data and remains a part of future investigation. Searchcoil magnetometer at Allahabad is providing continuous data and they are being examined to look into the seasonal pattern of these events. The present results should be considered as preliminary and first hand results for these type of events which has not been reported so far at low latitudes. Section 2 discusses in brief the type of instrumentation and analysis technique in brief, section 3 outlines the main results and provides the relevant discussions.

2. Instrumentation and data analysis

The results presented here were obtained from 3-channel search coil magnetometers acquired from Lviv centre of institute of space research, Ukrain. The instrument was deployed at a subtropical station Allahabad (Geomag. Lat. 16.05°N, Geomag. Long. 155°E). It consists of three search coils that record geomagnetic variation in three orthogonal directions viz. N-S, E-W and vertical. These coils are buried underground up to 3 ft to minimize local vibration and temperature effect. Data is downloaded to the computer with the help of the communication unit where the data cables from all the three coils are connected. Time synchronization is obtained by GPS receiver antenna which is connected to the communication unit. The sampling frequency of the instrument can go up to 256 Hz, but we operate the instrument at sampling rate 64 Hz to save the memory in the disc. The instrument can record signal of frequencies up to 30 Hz and therefore we can study right from geomagnetic pulsations up to ELF band. Down-sampling and filtering of the data may be required depending upon the frequency band we want to study.

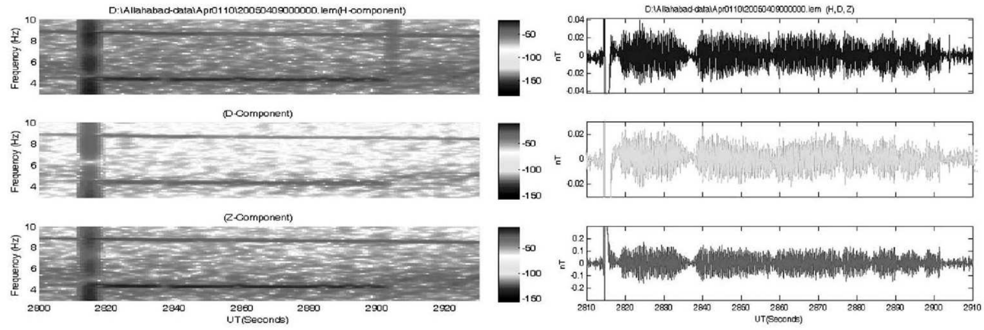

Figure 2. Type-1 pulsation observed at 0.8 hrs (UT) on 09 April 2005. The left panel shows the pulsation following a broad-band spike and right panel shows the temporal variations of the pulse amplitude.

In our case we examined one month data from April 2005 in different frequency regimes. Data were down-sampled by a factor of 64 to get information on Pc3, Pc4, Pc5 type of pulsations. Dynamic spectra were prepared taking the window of 512 points (512s) with the sliding of half the window size. This revealed the existence of pulsations in the lower frequency band of geomagnetic pulsations (Pc3, pc4, Pc5 types). Data were subjected to 50 mHz low pass butterworth filter of order 6 to look into the amplitude variation in the time series. We obtain multiple cases of Pc4 type of pulsations which are on the expected line at this latitude. To get the information of fundamental Schumann resonance and Pc1 type of pulses, we prepare the dynamic spectra of original data (sampling rate 64 Hz). For this purpose, we take window size of 1024 points (16 s) with the sliding of half the window size.

3. Results and discussions

Analysis of data reveals excitation of short-lived pulses at ~ 4 Hz other than the normal Pc-4 type. Though several cases of Pc4 are seen, we have presented here one typical example (Fig. 1). These are commonly occurring phenomena and not at all surprising at these locations. Here we concentrate on the observed short duration Pc1 events.

The dynamic spectra of the original data (sampling rate 64 Hz) revealed the existence of short lived pc1 types of pulsations which are not so common in this latitudinal region and have not been reported so far in the literature. Their characteristics are different from Pc1 events observed at latitudes away from the equator (Geomag. Lat.$> 20°$). Also, their characteristics were different in day time as compared to those observed during night hours. They were classified into two categories viz. Type-1 (observed during night hours) and Type-2 (observed during day hours). Statistics of one month data revealed that Type-1 events occurred more frequently and lived longer as compared to Type-2.

Type-1 (80-90 sec duration) pulses follow a broad-band spike of magnetic disturbance (Fig. 2), while Type-2 (30-40 sec duration) pulses do not show such features (Fig. 3). Type-1 pulses occur more frequently and are confined to post-sunset and pre-dawn hours. Both types of these pulses are of shorter duration (0.5 min to 1.5 min) as compared to those observed at low latitudes (Geomag. Lat.$> 20°$) not so near to the equator. From observations at low latitudes beyond subtropical regions ($> 20°$) Pc1 pulsations last from few minutes to half an hour (Webster & Fraser 1984). Also they fall in the lower frequency range (0.5 Hz to 2.1 Hz) as compared to the present observation where we observe pulses of frequency around 4.5 Hz.

We observe the simultaneous increase in the power of Schumann resonance for Type-2 pulses observed during day time (Fig. 3), whereas such increase was not obvious for Type-2 pulses observed during post-sunset hours (Fig. 2). Also, Type-1 events were more prevalent. Between 31 March, 2005 and 30 April, 2005 we observe 5 Type 1 pulses and 2 Type 2 pulses. These events were mostly observed during quiet geomagnetic conditions (cf. Table 1). Simultaneous enhancement in the power of Schumann resonance during Type 2 pulses suggest that they are induced by enhanced lightening activities. We call them Lightening Induced Pulses (LIPs). Above facts indicate that energizing phenomena confined to subtropical regions (Geomag. Lat.$< 20°$) are crucial in exciting these pulses. Higher frequency of the pulses suggest that disturbance of the local ionosphere in the ELF range such as enhanced lightening activities and F-layer irregularities could be responsible for such events. Lightening being transient phenomena could sustain these oscillations for smaller duration as compared to those sustained by F-layer irregularities. During post-sunset hours the low and equatorial latitude ionosphere is manifested with what is known as the spread-F. The spread F is associated with waves and turbulence covering a wide range of spatial and temporal scales and generated by a variety of instability processes persisting right through the night. The irregularities are field aligned and can provide free energy to sustain these oscillations. Also, F-layer irregularities are more prevalent as compared to enhanced lightening activities and we will expect Type-1 to occur more frequently as compared to Type-2. So, there is a possibility that Type-1 and Type-2 could have different excitation mechanisms. Enhancement in the power of Schumann Resonance is not that obvious in Type-1 pulses. Either they are masked due to high power in the broad-band spike or their generation mechanism is different from lightening. One of the possible candidates for exciting these pulses during post-sunset hours could be ionospheric irregularities as these are obvious energy sources at near-equator regions. It should be noted that structures of these pulses are different from those of ionospheric Alfvén resonance (Surkov et al. 2006). These waves are not so common at low latitudes and needs a careful look from theoretical points of view.

We could not get hold of the relevant ionospheric data to examine the role of F-layer irregularities in Type-1 pulses and it will be a part of the forthcoming studies. Nevertheless, the presence of broad-band spike preceding the event and its existence for longer duration indicate its role in exciting Type-1 pulses during post-sunset hours. The simultaneous enhancement in the Schumann resonance power during Type-2 event

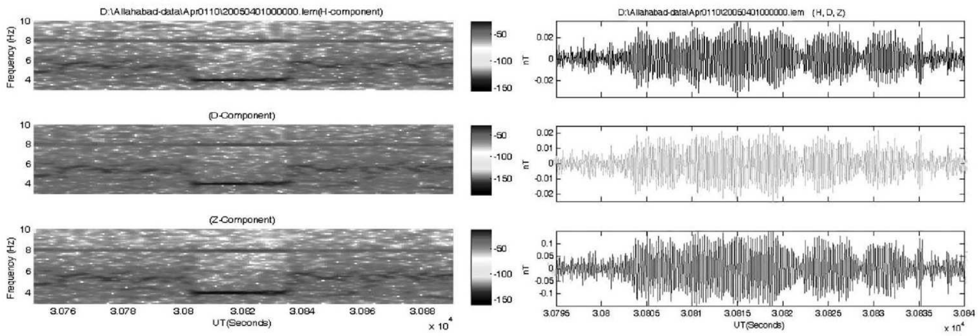

Figure 3. Type-2 pulsation observed at 8.56 hrs (UT) on 01 April 2005. The left panel shows the pulsations with the simultaneous enhancement in the power of first harmonic of Schumann resonance.

Table 1. Summary of events.

Pulse type	Date	UT (hour)	LT (hour)	K_p value
Type-1	31 Mar 2005	23.4	04.9(+1 day)	2+
Type-1	01 Apr 2005	15.4	20.9	1
Type-1	01 Apr 2005	17.9	23.4	1
Type-1	04 Apr 2005	23.6	05.1(+1 day)	6
Type-1	09 Apr 2005	00.8	06.3(+1 day)	2−
Type-2	01 Apr 2005	08.56	14.06	2+
Type-2	11 Apr 2005	06.12	11.63	0

during day time clearly suggest that they are lightening induced pc1 pulses and they are characteristics of subtropical regions as there is no reporting of such events from other latitudinal regions.

References

Hughes, W. J., & Southwood, D. J., 1976, JGR, 81, 3234

Nickolaenko, A. P., & Hayakawa, M., 2002, Resonance in the earth-ionosphere cavity, eds B. L. N. Kennett, Kluwer, Dordrecht, p. 91

Saito, T., 1983, Contribuciones cientificas para conmemorar of 75 aniversario del Observatorio del Ebro., eds J. O. Cardos & S. I. Roquetes, 175

Sentman, D. D., 1996, JGR, 101, 9479

Sinha, A. K., Pathan, B. M., Rajaram, R., & Rao, D. R. K., 2002, AnGeo, 20, 69

Sinha, A. K., & Rajaram, R., 2003, Earth Planet Space, 55, 93

Surkov, V. V., Hyakawa, M., Schekotov, A. Y., Fedorov, E. N., & Molchanov, O. A., 2006, JGR, 111, A01303

Webster, D. J., & Fraser, B. J., 1984, P&SS, 32, 935

Webster, D. J., & Fraser, B. J., 1985, P&SS, 33, 777